

Chapter 5

Pipe Materials Selection

CHAPTER 5 PIPE MATERIALS SELECTION

TABLE OF CONTENTS

PART	5.1	GENERAL	5-1
PART	5.2	PLASTIC PIPE CHARACTERISTICS	5-1
	5.2.1	Pressure Rating of Pipe	5-1
	5.2.2	How Temperature Affects Pressure Rating	5-1
	5.2.3	Freezing Water in Pipe	5-2
PART	5.3	POLYVINYL CHLORIDE (PVC) PLASTIC PIPE	5-2
PART	5.4	POLYETHYLENE (PE) PLASTIC PIPE	5-3
PART	5.5	ACRYLONITRILE-BUTADINE-STYRENE (ABS) PLASTIC PIPE	5-4
PART	5.6	POLYBUTYLENE (PB) PLASTIC PIPE	5-4
PART	5.7	STEEL PIPE	5-4
PART	5.8	FRICTION LOSS IN PIPING SYSTEM AT THE PUMP	5-5
PART	5.9	PIPE FRICTION LOSS TABLES	5-7

FIGURES

Figure	5.1	Estimate Friction Loss at Well	5-6
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TABLES

Table	5.1	PVC Plastic Pipe Reduction Due to Temperature	5-2
Table	5.2	Friction Loss PVC-SDR Pipe 160 psi	5-8
Table	5.3	Friction Loss PVC-SDR Pipe 200 psi	5-9
Table	5.4	Friction Loss PVC-SDR Pipe 250 psi	5-10
Table	5.5	Friction Loss PVC-SDR Pipe 315 psi	5-11
Table	5.6	Friction Loss PVC-IPS Pipe Schedule 40	5-12
Table	5.7	Friction Loss PVC-IPS Pipe Schedule 80	5-13
Table	5.8	Friction Loss PVC-IPS Pipe Schedule 120	5-14
Table	5.9	Friction Loss Polyethylene (PE) Pipe	5-15
Table	5.10	Friction Loss High Density Polyethylene (HDPE)	5-16
Table	5.11	Friction Loss IPS-ID Polybutylene Water Service Pipe, 160 psi	5-17
Table	5.12	Friction Loss CPS Polybutylene Water Service Pipe 160 psi	5-18
Table	5.13	Friction Loss CPS Polybutylene Water Service Pipe 250 psi	5-19
Table	5.14	Friction Loss Black or Galvanized Steel Pipe Schedule 40	5-20
Table	5.15	Friction Loss Black or Galvanized Steel Pipe Schedule 80	5-21

CHAPTER 5

PIPE MATERIALS SELECTION

5.1 GENERAL

There are several types of pipe that may be used in stockwater systems. The most commonly used types are discussed below. Usually, price per foot of pipe dictates the type of pipe that is used.

When designing a pipeline, it is important to know the type of pipe to be used. Internal pipe diameters vary depending on material type and pressure rating for a given nominal pipe size. Due to differing internal cross sectional area, and differing friction loss factors, friction loss in long pipelines can differ considerably from one type and rating of pipe to another.

5.2 PLASTIC PIPE CHARACTERISTICS

* 5.2.1 Pressure Rating of Pipe

Plastic pipe is rated at approximately half its tested rupture strength. This means that under normal temperature conditions, it can withstand occasional surge pressures up to twice its rated pressure.

Plastic pipe will weaken under repeated cycles of pressures in excess of those for which it is rated. The higher the surge pressure, the faster the pipe will weaken. For this reason, it is important to design the pipe system so that normal operating pressures are less than rated pressure of the pipe. The system should be designed and operated to limit the number and severity of pressure surges. Other sections of this manual describe ways to limit surge pressures.

5.2.2 How Temperature Affects Pressure Rating

The pressure rating of plastic pipe is determined at 73.4 degrees Fahrenheit (F). Strength of plastic pipe decreases as water temperature becomes warmer. In cases where warm well water is used, or where there is pipe exposure, water temperatures may exceed 73.4 degrees F. In that case, effective pressure rating of the pipe must be reduced.

* NEBRASKA NOTE

This is a description only. For design criteria, see Standard 516 of the FOTG, Section IV. For plastic pipe, the maximum working pressure shall not be more than the pressure rating of the pipe. The maximum working pressure is equal to the greater of: the maximum operating head plus surge or the maximum static head.

Table 5.1 lists the temperature reduction factors for PVC pipe.

Table 5.1
PVC PLASTIC PIPE RATING REDUCTION DUE TO TEMPERATURE

Temperature Degrees F	Multiply Pressure Rating by:
73.4	1.00
80	.93
90	.77
100	.67
110	.51
120	.43
130	.33
140	.23

5.2.3 Freezing of Water in Pipe

Plastic pipe containing static water should be drained when temperatures below 32 degrees F are expected. If the water is moving, freezing is unlikely above 0 degrees Fahrenheit.

If freezing does occur in the line, the pipe material will influence whether the pipe is damaged. In changing phase from liquid to ice, water expands approximately 10% by volume. Some plastic pipe will not survive the required 3.2% linear elongation, but most will.

Pipes most likely to be damaged by freezing water are those made of rigid materials, which include PVC and CPVC.

Pipe most unlikely to be damaged by freezing water include the cellulose-aceto-butyrate, acrylonitrile-butadine-styrene, styrene rubber, and polyethylene materials. All of these pipes have elongation and recovery properties which should in most cases enable it to expand and recover without permanent damage.

Although some pipe material can usually withstand freezing without damage, no system should be knowingly designed to freeze while full of water. Resistant pipes can be used in areas of severe exposure as an extra safety factor against damage by freezing. An excellent example of this is a shallow pipeline leading from a spring.

5.3 POLYVINYL CHLORIDE (PVC) PLASTIC PIPE

Polyvinyl Chloride (PVC) is a commonly used type of pipe used for stockwater pipelines. This is a rigid plastic pipe that, in the configuration used for stockwater pipelines, usually comes in 20-foot lengths. Connections are usually made with glued fittings, although rubber gasketed joints are sometimes used.

When subject to long-term exposure to ultraviolet radiation (sunlight), PVC pipe will suffer slow deterioration. PVC pipe should be buried or installed in an enclosure. If PVC must be exposed it should be coated or wrapped. The coating may be exterior latex paint. Make sure the pipe is thoroughly cleaned before painting.

Exposed pipe should be protected from mechanical damage by livestock or other hazards. Plastic pipe is particularly vulnerable when cold, as it will easily shatter.

There are two types of PVC pipe. Standard Dimension Ratio-Pressure Rated pipe (SDR-PR) is manufactured under specification ASTM D2241. PVC Iron Pipe Size (PVC-IPS) pipe is manufactured under specification ASTM D1785.

SDR-PR rated pipe is rated using standard dimension ratio and pressure as factors. This is the most common pipe type used in stockwater pipelines in Montana. Tables 5.2 through 5.5 list available sizes, pressure ratings and friction loss factors.

PVC-IPS pipe has various pressure ratings depending on nominal diameter and schedule designations. Schedule 40, 80, and 120 pipe are available. Tables 5.6 through 5.8 list available sizes, pressure ratings, and friction loss factors.

For both of these types of pipe, the outside diameter is constant and the inside diameter varies.

5.4 POLYETHYLENE (PE) PLASTIC PIPE

Polyethylene (PE) pipe is the second most common pipe used in stockwater pipelines. It is flexible, comes in coils and is used for most "pull-in" type systems. Where pipe is installed in trenches, it is harder to lay flat in the trench than PVC pipe. Since it comes in coils, PE pipe takes fewer fittings to lay. Connecting this type of pipe is usually done with "stab" type fittings held together with stainless steel band clamps. Frost heave in shallow pipelines tends to pull these joints apart. Double clamping is usually necessary to combat this problem.

There are several types of PE pipe. The one most commonly used in stockwater pipelines is a controlled inside diameter version rated by standard thermoplastic dimension ratio and pressure rating (SIDR-PR) and is manufactured under specification ASTM D2239. SIDR 15, 100 psi pipe is usually the most available polyethylene pipe.

Table 5.9 shows available sizes, pressure ratings, and friction loss factors.

A high density polyethylene pipe (HDPE) is available which can be used for above ground installations. This is the same type of pipe as used in hose reel type irrigation sprinkler systems. The material is tough, will withstand long term exposure to sunlight and may be used above ground where below ground installations are not possible. When used above ground it must be tied down so it will not pull apart and it must be protected or placed in a manner which will prevent mechanical damage. HDPE is only available in sizes 1-1/2 inch and larger.

This material is tough, flexible, and resistant to freeze damage. Although sometimes proposed for shallow non-drained pipelines, it should not be used in this way. This pipe will usually withstand freezing

without damage, but the system should not be knowingly designed to freeze while water is in the line.

Table 5.10 tabulates available sizes, pressure ratings, and friction loss factors.

5.5 ACRYLONITRILE-BUTADIENE-STYRENE (ABS) PLASTIC PIPE

Although listed in the standards as an acceptable pipe material, ABS pipe is used little in the transmission pipeline portions of stockwater pipelines. ABS pipe is frequently used in stockwater systems as drain, vent, and waste system components. This black pipe has the advantages of being tough with good strength and stiffness. It is not tolerant to ultraviolet light, so it should be painted or wrapped if exposed to sunlight. It ranges in size from 1/8-inch to 12 inches in diameter.

5.6 POLYBUTYLENE (PB) PLASTIC PIPE

Polybutylene pipe, which is an alternative now sometimes used in household plumbing and underground water service, is occasionally used in stockwater pipeline applications.

This material is tough, flexible, and resistant to freeze damage. Although sometimes proposed for shallow non-drained pipelines which freeze in the winter, it should not be used in this way. This pipe will usually withstand freezing without damage, but the system should not be designed to freeze with water in the line.

Tables 5.11 through 5.13 tabulate available sizes, pressure ratings, and friction loss factors.

5.7 STEEL PIPE

Steel pipe is often used in system plumbing next to the pump. It is rarely used in main parts of the pipeline in buried installations.

Steel pipe is used in buried applications only as a last resort due to its high cost, high friction loss, and because it easily corrodes.

Galvanized pipe should be used for exposed installations such as at cable supported aerial stream crossings, and as plumbing in manholes. When buried, steel pipe should always be coated and wrapped. This is due to the corrosive nature of most soils in Montana.

Some water in Montana is highly corrosive. When long sections of steel pipe are used which cannot be easily replaced, then a sample of the water supply should be taken and a Lanelier Index run on the sample. If the test shows the water to be highly corrosive, unlined steel pipe should not be used. Analysis by the Lanelier Index is beyond the scope of this manual and should be referred to State or Area Engineering staff with knowledge of its use.

Occasionally, steel pipe must be used for very high pressure pipelines where plastic pipe is not available with adequate pressure ratings. Operating pressures in steel pipe should not exceed 50 percent of the rated bursting pressure. Tables 5.14 through 5.15 tabulate pressure ratings corrected to 50 percent of rated bursting pressure. These tables also show available sizes and friction loss factors.

5.8 FRICTION LOSS IN PIPING SYSTEM AT THE PUMP

Friction losses in the plumbing at the pump is significant enough that it should be considered when determining total dynamic pumping head. The typical pipe material used between a submersible pump and pressure tank is polyethylene pipe with some steel pipe at the pressure tank. High pressure systems sometimes use steel pipe between pump and pressure tank.

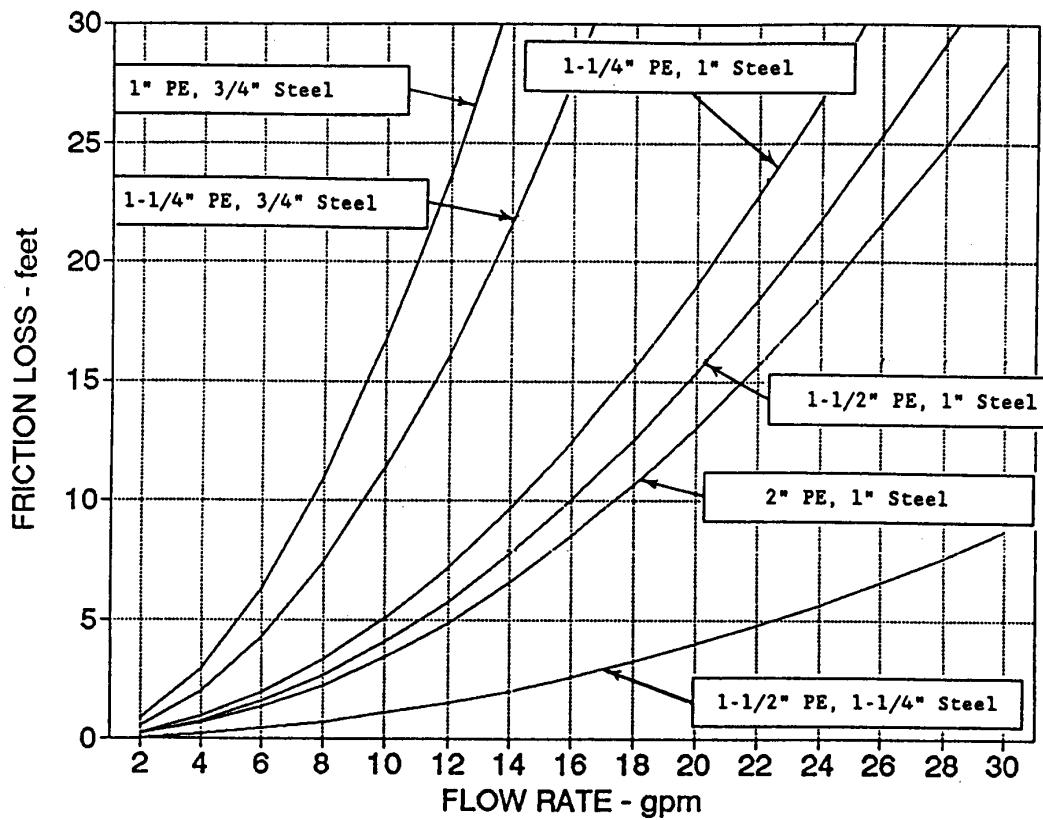
The plumbing elements for an automatic pressure system and a manual or timed system are about the same. Figure 5.1 is a graph which shows estimated friction loss values that can be used for most pumped flow installations.

Figure 5.1 assumes the following conditions:

- 100 feet pump depth in well
- PE pipe between pump and pressure tank
 - (100 ft + 25 ft to manhole/tank - 125 ft length of PE pipe)
- 15 feet of galvanized steel pipe at manhole
- 4 90 degree elbows in steel pipe
- 1 "T" in steel pipe
- 1 open gate valve in steel pipe
- 1 check valve in steel pipe.

The friction loss in PE pipe is so low that well depths different than the assumed 100 feet will make little difference in total friction loss. If the total plumbing system is significantly different than assumed above, special calculations should be performed. If steel pipe is used to drop the pump in the well, special computations must be made.

**Figure 5. 1
ESTIMATED FRICTION LOSS AT WELL**



Curve Type

- (1) 1" PE connector pipe, 3/4" steel plumbing at tank
- (2) 1-1/4" PE connector pipe, 3/4" steel plumbing at tank
- (3) 1-1/2" PE connector pipe, 1" steel plumbing at tank
- (4) 2" PE connector pipe, 1" steel plumbing at tank
- (5) 1-1/2" PE connector pipe, 1-1/4" steel plumbing at tank
- (6) 2-1/2" PE connector pipe, 1-1/4" steel plumbing at tank

Note:

The above chart is based on:
 100 feet to water surface in well
 PE connector pipe
 15 feet of steel pipe
 4 steel pipe elbows
 1 steel "T"
 1 gate valve in steel pipe
 1 check valve in steel pipe

5.9 PIPE FRICTION LOSS TABLES

The following tables are based on friction loss by the Hazen Williams formula. The form of the equation used is:

$$H_f = L \left(\frac{gpm}{C} \right)^{1.85185} \frac{10.4057}{d_i^{4.87037}}$$

C = Hazen-Williams friction loss factor

gpm = Flow rate in gallons per minute

d_i = Pipe inside diameter

L = Length of pipe segment (100-feet used in calcs).

Table 5.2
PVC-SDR PIPE
FRICITION LOSS ft/100 ft
SDR 26, Pressure Rating = 160 psi @ 73.4° F
Hazen Williams C = 150

Q gallons per min.	1 inch 0.0078 A 1.195 ID	1-1/4 inch 0.0128 A 1.532 ID	1-1/2 inch 0.0168 A 1.754 ID	2 inch 0.0262 A 2.193 ID	2-1/2 inch 0.0384 A 2.655 ID	3 inch 0.0569 A 3.230 ID	3-1/2 inch 0.0743 A 3.692 ID	4 inch 0.0941 A 4.154 ID
1	0.0408	0.0122	0.0063	0.0021	0.0008	0.0003	0.0002	0.0001
2	0.1473	0.0439	0.0227	0.0077	0.0030	0.0012	0.0006	0.0003
3	0.3120	0.0931	0.0481	0.0162	0.0064	0.0025	0.0013	0.0007
4	0.5316	0.1585	0.0820	0.0276	0.0109	0.0042	0.0022	0.0012
5	0.8036	0.2397	0.1240	0.0418	0.0165	0.0063	0.0033	0.0019
6	1.1264	0.3359	0.1738	0.0585	0.0231	0.0089	0.0046	0.0026
7	1.4985	0.4469	0.2312	0.0779	0.0307	0.0118	0.0062	0.0035
8	1.9189	0.5722	0.2960	0.0997	0.0393	0.0151	0.0079	0.0044
9	2.3866	0.7117	0.3682	0.1241	0.0489	0.0188	0.0098	0.0055
10	2.9008	0.8651	0.4475	0.1508	0.0594	0.0229	0.0119	0.0067
11	3.4607	1.0321	0.5339	0.1799	0.0709	0.0273	0.0142	0.0080
12	4.0658	1.2125	0.6273	0.2113	0.0833	0.0321	0.0167	0.0094
13	4.7154	1.4062	0.7275	0.2451	0.0966	0.0372	0.0194	0.0109
14	5.4091	1.6131	0.8345	0.2812	0.1108	0.0427	0.0222	0.0125
15	6.1463	1.8329	0.9482	0.3195	0.1259	0.0485	0.0253	0.0142
16	6.9265	2.0656	1.0686	0.3600	0.1419	0.0546	0.0285	0.0160
17	7.7495	2.3110	1.1956	0.4028	0.1588	0.0611	0.0319	0.0179
18	(1)	2.5691	1.3290	0.4478	0.1765	0.0679	0.0354	0.0199
19	(1)	2.8396	1.4690	0.4949	0.1951	0.0751	0.0392	0.0220
20	(1)	3.1226	1.6154	0.5443	0.2145	0.0826	0.0431	0.0242
21	(1)	3.4178	1.7681	0.5957	0.2348	0.0904	0.0471	0.0265
22	(1)	3.7253	1.9272	0.6493	0.2559	0.0985	0.0514	0.0289
23	(1)	4.0450	2.0926	0.7050	0.2779	0.1070	0.0558	0.0314
24	(1)	4.3767	2.2642	0.7628	0.3007	0.1157	0.0603	0.0340
25	(1)	4.7203	2.4420	0.8227	0.3243	0.1248	0.0651	0.0367

- (1) Exceeds 5.0 feet per second velocity
- (2) A = Flow area, square feet
- (3) For ASTM D2241, materials 1120, 1120 or 2120. These are the most commonly used materials. Other materials have different ratings, see ASTM D2241.

Table 5.3
PVC-SDR PIPE
FRICITION LOSS ft/100 ft
SDR 21, Pressure Rating = 200 psi @ 73.40° F
Hazen Williams C = 150

Q Gallons per min.	1 inch 0.0077 A 1.198 ID	1-1/4 inch 0.0123 A 1.502 ID	1-1/2 inch 0.0161 A 1.720 ID	2 inch 0.0252 A 2.149 ID	2-1/2 inch 0.0369 A 2.601 ID	3 inch 0.0547 A 3.166 ID	3-1/2 inch 0.0715 A 3.620 ID	4 inch 0.0904 A 4.072 ID
1	0.0403	0.0134	0.0069	0.0023	0.0009	0.0004	0.0002	0.0001
2	0.1455	0.0484	0.0250	0.0084	0.0033	0.0013	0.0007	0.0004
3	0.3083	0.1025	0.0530	0.0179	0.0071	0.0027	0.0014	0.0008
4	0.5252	0.1746	0.0902	0.0305	0.0120	0.0046	0.0024	0.0014
5	0.7939	0.2639	0.1364	0.0461	0.0182	0.0070	0.0036	0.0021
6	1.1127	0.3699	0.1912	0.0646	0.0255	0.0098	0.0051	0.0029
7	1.4803	0.4921	0.2543	0.0860	0.0339	0.0130	0.0068	0.0038
8	1.8956	0.6301	0.3257	0.1101	0.0434	0.0167	0.0087	0.0049
9	2.3576	0.7837	0.4050	0.1369	0.0540	0.0207	0.0108	0.0061
10	2.8656	0.9525	0.4923	0.1664	0.0657	0.0252	0.0131	0.0074
11	3.4187	1.1364	0.5873	0.1985	0.0784	0.0301	0.0157	0.0088
12	4.0165	1.3351	0.6900	0.2333	0.0921	0.0353	0.0184	0.0104
13	4.6582	1.5484	0.8002	0.2705	0.1068	0.0410	0.0213	0.0120
14	5.3434	1.7762	0.9180	0.3103	0.1225	0.0470	0.0245	0.0138
15	6.0717	2.0182	1.0431	0.3526	0.1392	0.0534	0.0278	0.0157
16	6.8425	2.2745	1.1755	0.3974	0.1568	0.0602	0.0313	0.0177
17	7.6554	2.5447	1.3151	0.4446	0.1755	0.0674	0.0351	0.0198
18	(1)	2.8288	1.4620	0.4942	0.1951	0.0749	0.0390	0.0220
19	(1)	3.1267	1.6159	0.5463	0.2156	0.0828	0.0431	0.0243
20	(1)	3.4383	1.7770	0.6007	0.2371	0.0910	0.0474	0.0267
21	(1)	3.7634	1.9450	0.6575	0.2595	0.0996	0.0519	0.0292
22	(1)	4.1020	2.1200	0.7167	0.2828	0.1086	0.0565	0.0319
23	(1)	4.4539	2.3019	0.7782	0.3071	0.1179	0.0614	0.0346
24	(1)	4.8192	2.4906	0.8420	0.3323	0.1276	0.0664	0.0374
25	(1)	5.1976	2.6862	0.9081	0.3584	0.1376	0.0716	0.0404

(1) Exceeds 5.0 feet per second velocity

(2) A = Flow area, square feet

(3) For ASTM D2241, materials 1120, 1120 or 2120. These are the most commonly used materials. Other materials have different ratings, see ASTM D2241.

Table 5.4
PVC-SDR PIPE
FRICITION LOSS ft/100 ft
SDR 17, Pressure Rating = 250 psi @ 73.4° F
Hazen Williams C = 150

Q Gallons per min.	1 inch 0.0074 A 1.162 ID	1-1/4 inch 0.0117 A 1.464 ID	1-1/2 inch 0.0153 A 1.676 ID	2 inch 0.0239 A 2.095 10	2-1/2 inch 0.0351 A 2.537 ID	3 inch 0.0520 A 3.088 ID	3-1/2 inch 0.0680 A 3.530 ID	4 inch 0.0860 A 3.970 ID
1	0.0470	0.0152	0.0079	0.0026	0.0010	0.0004	0.0002	0.0001
2	0.1695	0.0548	0.0284	0.0096	0.0038	0.0014	0.0008	0.0004
3	0.3592	0.1161	0.0601	0.0203	0.0080	0.0031	0.0016	0.0009
4	0.6118	0.1978	0.1024	0.0345	0.0136	0.0052	0.0027	0.0015
5	0.9249	0.2990	0.1547	0.0522	0.0205	0.0079	0.0041	0.0023
6	1.2964	0.4190	0.2169	0.0731	0.0288	0.0111	0.0058	0.0033
7	1.7247	0.5575	0.2885	0.0973	0.0383	0.0147	0.0077	0.0043
8	2.2085	0.7139	0.3695	0.1246	0.0491	0.0188	0.0098	0.0055
9	2.7468	0.8879	0.4595	0.1550	0.0610	0.0234	0.0122	0.0069
10	3.3386	1.0791	0.5585	0.1884	0.0742	0.0285	0.0148	0.0084
11	3.9831	1.2875	0.6663	0.2247	0.0885	0.0340	0.0177	0.0100
12	4.6795	1.5126	0.7828	0.2640	0.1039	0.0399	0.0208	0.0117
13	5.4272	1.7542	0.9079	0.3062	0.1205	0.0463	0.0241	0.0136
14	6.2255	2.0123	1.0414	0.3513	0.1383	0.0531	0.0277	0.0156
15	7.0740	2.2865	1.1834	0.3992	0.1571	0.0603	0.0314	0.0177
16	7.9720	2.5768	1.3336	0.4498	0.1771	0.0680	0.0354	0.0200
17	(1)	2.8830	1.4921	0.5033	0.1981	0.0761	0.0396	0.0224
18	(1)	3.2048	1.6587	0.5595	0.2202	0.0846	0.0441	0.0249
19	(1)	3.5423	1.8333	0.6184	0.2434	0.0935	0.0487	0.0275
20	(1)	3.8953	2.0160	0.6800	0.2677	0.1028	0.0536	0.0302
21	(1)	4.2637	2.2066	0.7443	0.2930	0.1125	0.0586	0.0331
22	(1)	4.6472	2.4052	0.8113	0.3193	0.1226	0.0639	0.0361
23	(1)	5.0460	2.6115	0.8809	0.3467	0.1331	0.0694	0.0392
24	(1)	5.4598	2.8257	0.9531	0.3752	0.1440	0.0751	0.0424
25	(1)	5.8885	3.0476	1.0279	0.4046	0.1554	0.0810	0.0457

- (1) Exceeds 5.0 feet per second velocity
- (2) A = Flow area, square feet
- (3) For ASTM D2241, materials 1120, 1120 or 2120. These are the most commonly used materials. Other materials have different ratings, see ASTM D2241.

Table 5.5
PVC-SDR PIPE
FRICITION LOSS ft/100 ft
SDR 13.5, Pressure Rating = 315 psi @ 73.4° F
Hazen Williams C = 150

Q Gallons per min.	1 inch 0.0069 A 1.121 ID	1-1/4 inch 0.0109 A 1.414 ID	1-1/2 inch 0.0143 A 1.618 ID	2 inch 0.0223 A 2.023 ID	2-1/2 inch 0.0327 A 2.449 ID	3 inch 0.0485 A 2.982 ID	3-1/2 inch 0.0633 A 3.408 ID	4 inch 0.0802 A 3.834 ID
1	0.0557	0.0180	0.0093	0.0031	0.0012	0.0005	0.0002	0.0001
2	0.2011	0.0649	0.0337	0.0113	0.0045	0.0017	0.0009	0.0005
3	0.4260	0.1375	0.0713	0.0240	0.0095	0.0036	0.0019	0.0011
4	0.7258	0.2342	0.1215	0.0409	0.0161	0.0062	0.0032	0.0018
5	1.0972	0.3541	0.1837	0.0619	0.0244	0.0094	0.0049	0.0027
6	1.5378	0.4963	0.2575	0.0867	0.0342	0.0131	0.0068	0.0039
7	2.0459	0.6603	0.3425	0.1154	0.0455	0.0174	0.0091	0.0051
8	2.6198	0.8455	0.4386	0.1478	0.0583	0.0223	0.0117	0.0066
9	3.2583	1.0516	0.5455	0.1838	0.0725	0.0278	0.0145	0.0082
10	3.9603	1.2782	0.6630	0.2234	0.0881	0.0338	0.0176	0.0099
11	4.7248	1.5249	0.7910	0.2665	0.1051	0.0403	0.0210	0.0118
12	5.5509	1.7915	0.9293	0.3131	0.1234	0.0473	0.0247	0.0139
13	6.4378	2.0777	1.0778	0.3631	0.1432	0.0549	0.0286	0.0161
14	7.3848	2.3834	1.2363	0.4165	0.1642	0.0629	0.0328	0.0185
15	8.3912	2.7082	1.4048	0.4733	0.1866	0.0715	0.0373	0.0210
16	(1)	3.0520	1.5832	0.5334	0.2103	0.0806	0.0421	0.0237
17	(1)	3.4146	1.7713	0.5967	0.2353	0.0902	0.0471	0.0265
18	(1)	3.7958	1.9690	0.6633	0.2615	0.1002	0.0523	0.0295
19	(1)	4.1956	2.1764	0.7332	0.2891	0.1108	0.0578	0.0326
20	(1)	4.6137	2.3932	0.8063	0.3179	0.1218	0.0636	0.0358
21	(1)	5.0499	2.6195	0.8825	0.3479	0.1334	0.0696	0.0392
22	(1)	5.5042	2.8552	0.9619	0.3792	0.1453	0.0759	0.0427
23	(1)	5.9765	3.1002	1.0444	0.4118	0.1578	0.0824	0.0464
24	(1)	6.4666	3.3544	1.1301	0.4456	0.1708	0.0891	0.0502
25	(1)	(1)	3.6178	1.2188	0.4805	0.1842	0.0961	0.0542

- (1) Exceeds 5.0 feet per second velocity
- (2) A = Flow area, square feet
- (3) For ASTM D2241, materials 1120, 1120 or 2120. These are the most commonly used materials. Other materials have different ratings, see ASTM D2241.

Table 5.6
PVC-IPS SCHEDULE RATED PIPE
FRICITION LOSS ft/100 ft
Schedule 40 (3)
Hazen Williams C = 150

Q Gallons per min.	1 inch	1-1/4 inch	1-1/2 inch	2 inch	2-1/2 inch	3 inch	3-1/2 inch	4 inch
	450 psi	370 psi	330 psi	280 psi	300 psi	260 psi	240 psi	220 psi
	0.0060 A	0.0104 A	0.0141 A	0.0233 A	0.0332 A	0.0513 A	0.0687 A	0.0884 A
	1.049 ID	1.380 ID	1.610 ID	2.067 ID	2.469 ID	3.068 ID	3.548 ID	4.026 ID
1	0.0770	0.0202	0.0096	0.0028	0.0012	0.0004	0.0002	0.0001
2	0.2778	0.0731	0.0345	0.0102	0.0043	0.0015	0.0007	0.0004
3	0.5886	0.1548	0.0731	0.0216	0.0091	0.0032	0.0016	0.0008
4	1.0028	0.2637	0.1245	0.0369	0.0155	0.0054	0.0027	0.0014
5	1.5159	0.3987	0.1882	0.0557	0.0234	0.0081	0.0040	0.0022
6	2.1248	0.5588	0.2637	0.0781	0.0329	0.0114	0.0056	0.0030
7	2.8267	0.7434	0.3509	0.1039	0.0437	0.0152	0.0075	0.0040
8	3.6198	0.9519	0.4493	0.1331	0.0560	0.0194	0.0096	0.0052
9	4.5020	1.1839	0.5588	0.1655	0.0696	0.0242	0.0119	0.0064
10	5.4720	1.4390	0.6792	0.2011	0.0846	0.0294	0.0145	0.0078
11	6.5282	1.7168	0.8103	0.2400	0.1010	0.0351	0.0173	0.0093
12	7.6696	2.0170	0.9520	0.2819	0.1186	0.0412	0.0203	0.0110
13	8.8950	2.3392	1.1041	0.3270	0.1376	0.0478	0.0235	0.0127
14	(1)	2.6833	1.2665	0.3751	0.1578	0.0548	0.0270	0.0146
15	(1)	3.0490	1.4391	0.4262	0.1793	0.0623	0.0307	0.0166
16	(1)	3.4361	1.6218	0.4803	0.2021	0.0702	0.0346	0.0187
17	(1)	3.8443	1.8145	0.5374	0.2261	0.0785	0.0387	0.0209
18	(1)	4.2736	2.0171	0.5973	0.2514	0.0873	0.0430	0.0232
19	(1)	4.7236	2.2296	0.6603	0.2779	0.0965	0.0475	0.0257
20	(1)	5.1943	2.4517	0.7260	0.3055	0.1061	0.0523	0.0282
21	(1)	5.6855	2.6836	0.7947	0.3344	0.1161	0.0572	0.0309
22	(1)	6.1970	2.9250	0.8662	0.3645	0.1266	0.0623	0.0337
23	(1)	6.7287	3.1760	0.9405	0.3958	0.1374	0.0677	0.0366
24	(1)	(1)	3.4364	1.0176	0.4283	0.1487	0.0732	0.0396
25	(1)	(1)	3.7062	1.0976	0.4619	0.1604	0.0790	0.0427

(1) Exceeds 5.0 feet per second velocity

(2) A = Flow area, square feet

(3) For ASTM D2241, materials 1120, 1120 or 2120. These are the most commonly used materials. Other materials have different ratings, see ASTM D2241. Pressure rating is at 73.4° F.

Table 5.7
PVC-IPS SCHEDULE RATED PIPE
FRICITION LOSS ft/100 ft
Schedule 80 (3)
Hazen Williams C = 150

Q Gallons per min.	1 inch	1-1/4 inch	1-1/2 inch	2 inch	2-1/2 inch	3 inch	3-1/2 inch	4 inch
	630 psi	520 psi	470 psi	400 psi	420 psi	370 psi	350 psi	320 psi
	0.0050 A	0.0089 A	0.0123 A	0.0205 A	0.0294 A	0.0459 A	0.0617 A	0.0798 A
	0.957 ID	1.278 ID	1.500 ID	1.939 ID	2.323 ID	2.900 ID	3.364 ID	3.826 ID
1	0.1203	0.0294	0.0135	0.0039	0.0016	0.0005	0.0003	0.0001
2	0.4344	0.1062	0.0487	0.0139	0.0058	0.0020	0.0010	0.0005
3	0.9204	0.2250	0.1031	0.0295	0.0123	0.0042	0.0020	0.0011
4	1.5681	0.3833	0.1757	0.0503	0.0209	0.0071	0.0034	0.0018
5	2.3704	0.5795	0.2656	0.0761	0.0316	0.0107	0.0052	0.0028
6	3.3225	0.8122	0.3723	0.1066	0.0442	0.0150	0.0073	0.0039
7	4.4202	1.0805	0.4953	0.1419	0.0588	0.0200	0.0097	0.0052
8	5.6602	1.3836	0.6342	0.1817	0.0753	0.0256	0.0124	0.0066
9	7.0397	1.7209	0.7888	0.2259	0.0937	0.0318	0.0154	0.0082
10	8.5564	2.0916	0.9587	0.2746	0.1139	0.0387	0.0188	0.0100
11	10.2081	2.4954	1.1438	0.3276	0.1359	0.0461	0.0224	0.0120
12	(1)	2.9317	1.3438	0.3849	0.1596	0.0542	0.0263	0.0141
13	(1)	3.4001	1.5585	0.4464	0.1852	0.0628	0.0305	0.0163
14	(1)	3.9002	1.7877	0.5121	0.2124	0.0721	0.0350	0.0187
15	(1)	4.4318	2.0314	0.5818	0.2413	0.0819	0.0398	0.0212
16	(1)	4.9944	2.2893	0.6557	0.2720	0.0923	0.0448	0.0239
17	(1)	5.5878	2.5613	0.7336	0.3043	0.1033	0.0501	0.0268
18	(1)	6.2117	2.8472	0.8155	0.3383	0.1148	0.0557	0.0298
19	(1)	6.8658	3.1471	0.9014	0.3739	0.1269	0.0616	0.0329
20	(1)	(1)	3.4607	0.9912	0.4111	0.1396	0.0677	0.0362
21	(1)	(1)	3.7879	1.0850	0.4500	0.1527	0.0741	0.0396
22	(1)	(1)	4.1287	1.1826	0.4905	0.1665	0.0808	0.0432
23	(1)	(1)	4.4829	1.2841	0.5326	0.1808	0.0877	0.0469
24	(1)	(1)	4.8506	1.3893	0.5763	0.1956	0.0949	0.0507
25	(1)	(1)	5.2315	1.4984	0.6215	0.2110	0.1024	0.0547

(1) Exceeds 5.0 feet per second velocity

(2) A = Flow area, square feet

(3) For ASTM D2241, materials 1120, 1120 or 2120. These are the most commonly used materials. Other materials have different ratings, see ASTM D2241. Pressure rating is at 73.4° F.

Table 5.8
PVC-IPS SCHEDULE RATED PIPE
FRICITION LOSS ft/100 ft
Schedule 120 (3)
Hazen Williams C = 150

Q Gallons per min.	1 inch	1-1/4 inch	1-1/2 inch	2 inch	2-1/2 inch	3 inch	3-1/2 inch	4 inch
	720 psi	600 psi	540 psi	470 psi	470 psi	440 psi	380 psi	430 psi
	0.0060 A	0.0104 A	0.0141 A	0.0233 A	0.0332 A	0.0513 A	0.0687 A	0.0884 A
	0.915 ID	1.230 ID	1.450 ID	1.875 ID	2.275 ID	2.800 ID	3.300 ID	3.626 ID
1	0.1498	0.0354	0.0159	0.0045	0.0018	0.0006	0.0003	0.0002
2	0.5405	0.1280	0.0574	0.0164	0.0064	0.0023	0.0010	0.0007
3	1.1453	0.2711	0.1216	0.0348	0.0136	0.0049	0.0022	0.0014
4	1.9512	0.4619	0.2072	0.0593	0.0231	0.0084	0.0038	0.0024
5	2.9496	0.6982	0.3133	0.0896	0.0349	0.0127	0.0057	0.0036
6	4.1342	0.9786	0.4391	0.1256	0.0490	0.0178	0.0080	0.0051
7	5.5000	1.3020	0.5842	0.1671	0.0651	0.0237	0.0106	0.0067
8	7.0430	1.6672	0.7481	0.2139	0.0834	0.0303	0.0136	0.0086
9	8.7596	2.0736	0.9304	0.2661	0.1037	0.0377	0.0170	0.0107
10	10.6468	2.5203	1.1308	0.3234	0.1261	0.0459	0.0206	0.0130
11	(1)	3.0068	1.3491	0.3858	0.1504	0.0547	0.0246	0.0155
12	(1)	3.5325	1.5850	0.4533	0.1767	0.0643	0.0289	0.0183
13	(1)	4.0970	1.8383	0.5257	0.2050	0.0746	0.0335	0.0212
14	(1)	4.6996	2.1087	0.6030	0.2351	0.0855	0.0384	0.0243
15	(1)	5.3401	2.3961	0.6852	0.2672	0.0972	0.0437	0.0276
16	(1)	6.0180	2.7003	0.7722	0.3011	0.1095	0.0492	0.0311
17	(1)	6.7331	3.0211	0.8639	0.3369	0.1225	0.0550	0.0348
18	(1)	7.4848	3.3584	0.9604	0.3745	0.1362	0.0612	0.0387
19	(1)	(1)	3.7121	1.0615	0.4139	0.1506	0.0676	0.0427
20	(1)	(1)	4.0819	1.1673	0.4552	0.1656	0.0744	0.0470
21	(1)	(1)	4.4679	1.2776	0.4982	0.1812	0.0814	0.0515
22	(1)	(1)	4.8699	1.3926	0.5430	0.1975	0.0887	0.0561
23	(1)	(1)	5.2877	1.5121	0.5896	0.2145	0.0963	0.0609
24	(1)	(1)	5.7214	1.6361	0.6380	0.2321	0.1042	0.0659
25	(1)	(1)	6.1706	1.7646	0.6881	0.2503	0.1124	0.0711

(1) Exceeds 5.0 feet per second velocity

(2) A = Flow area, square feet

(3) For ASTM D2241, materials 1120, 1120 or 2120. These are the most commonly used materials. Other materials have different ratings, see ASTM D2241. Pressure rating is at 73.4° F.

Table 5.9
POLYETHYLENE (PE) SDR-RATED PIPE
FRICITION LOSS ft/100 ft
ASTM D2239 (3)
Hazen Williams C = 145

Q Gallons per min.	1 inch	1-1/4 inch	1-1/2 inch	2 inch	2-1/2 inch	3 inch	4 inch
	0.0060 A 1.049 ID	0.0104 A 1.380 ID	0.0141 A 1.610 ID	0.0233 A 2.069 ID	0.0333 A 2.469 ID	0.0513 A 3.068 ID	0.0884 A 4.026 ID
1	0.0820	0.0216	0.0102	0.0030	0.0013	0.0004	0.0001
2	0.2958	0.0778	0.0367	0.0109	0.0046	0.0016	0.0004
3	0.6268	0.1648	0.0778	0.0230	0.0097	0.0034	0.0009
4	1.0678	0.2808	0.1325	0.0393	0.0165	0.0057	0.0015
5	1.6142	0.4245	0.2004	0.0593	0.0250	0.0087	0.0023
6	2.2624	0.5950	0.2808	0.0832	0.0350	0.0122	0.0032
7	3.0099	0.7915	0.3736	0.1106	0.0466	0.0162	0.0043
8	3.8543	1.0136	0.4784	0.1417	0.0596	0.0207	0.0055
9	4.7937	1.2606	0.5950	0.1762	0.0742	0.0257	0.0069
10	5.8265	1.5322	0.7232	0.2142	0.0901	0.0313	0.0083
11	6.9512	1.8280	0.8628	0.2555	0.1075	0.0373	0.0099
12	8.1666	2.1476	1.0137	0.3002	0.1263	0.0439	0.0117
13	9.4714	2.4908	1.1757	0.3482	0.1465	0.0509	0.0135
14	(1)	2.8572	1.3486	0.3994	0.1681	0.0583	0.0155
15	(1)	3.2466	1.5324	0.4538	0.1910	0.0663	0.0176
16	(1)	3.6587	1.7269	0.5114	0.2152	0.0747	0.0199
17	(1)	4.0934	1.9321	0.5722	0.2408	0.0836	0.0223
18	(1)	4.5505	2.1478	0.6361	0.2677	0.0929	0.0247
19	(1)	5.0297	2.3740	0.7030	0.2959	0.1027	0.0273
20	(1)	5.5308	2.6106	0.7731	0.3253	0.1130	0.0301
21	(1)	6.0538	2.8574	0.8462	0.3561	0.1236	0.0329
22	(1)	6.5985	3.1145	0.9223	0.3881	0.1348	0.0359
23	(1)	7.1646	3.3817	1.0015	0.4214	0.1463	0.0389
24	(1)	(1)	3.6590	1.0836	0.4560	0.1583	0.0421
25	(1)	(1)	3.9464	1.1687	0.4918	0.1707	0.0455

AVAILABLE PE PIPE SIZES AND RATINGS

Available Sizes	SDR	Pressure Rating @ 73.4° F
1, 1-1/2, 2	15	80
1, 1-1/2, 2	11.5	100
1, 1-1/2, 2	9	125
1, 1-1/2, 2, 2-1/2, 3, 4	7	160
1, 1-1/2, 2, 2-1/2, 3, 4	5.3	200

(1) Exceeds 5.0 feet per second velocity

(2) A = Flow area, square feet

(3) For ASTM D2239, material PE3408. This is the most commonly used material. Other materials have different ratings, see ASTM D2239.

Table 5.10
HIGH DENSITY POLYETHYLENE (HOPE)
FRICITION LOSS ft/100 ft
ASTM D1248, Type III
Hazen Williams C = 150

Q Gallons per min.	1-1/2 inch	2 inch	1-1/2 inch	2 inch	1-1/2 inch	2 inch	1-1/2 inch	2 inch
	130 psi SDR 13.5 0.0143 A 1.62 ID	130 psi SDR 13.5 0.0220 A 2.01 ID	160 psi SDR 11 0.0131 A 1.55 ID	160 psi SDR 11 0.0203 A 1.93 ID	200 psi SDR 9 0.0119 A 1.48 ID	200 psi SDR 9 0.0183 A 1.83 ID	255 psi SDR 7.3 0.0104 A 1.38 ID	255 psi SDR 7.3 0.0159 A 1.71 ID
1	0.0093	0.0032	0.0115	0.0040	0.0144	0.0051	0.0202	0.0071
2	0.0335	0.0117	0.0415	0.0143	0.0520	0.0185	0.0731	0.0257
3	0.0709	0.0248	0.0879	0.0302	0.1101	0.0392	0.1548	0.0545
4	0.1208	0.0422	0.1498	0.0515	0.1876	0.0667	0.2637	0.0928
5	0.1826	0.0639	0.2264	0.0778	0.2835	0.1008	0.3987	0.1403
6	0.2559	0.0895	0.3173	0.1091	0.3974	0.1413	0.5588	0.1967
7	0.3405	0.1191	0.4222	0.1451	0.5287	0.1880	0.7434	0.2616
8	0.4360	0.1525	0.5406	0.1858	0.6771	0.2408	0.9519	0.3350
9	0.5422	0.1896	0.6724	0.2311	0.8421	0.2995	1.1839	0.4167
10	0.6590	0.2305	0.8172	0.2809	1.0235	0.3640	1.4390	0.5065
11	0.7863	0.2750	0.9750	0.3351	1.2211	0.4343	1.7168	0.6042
12	0.9237	0.3231	1.1454	0.3937	1.4346	0.5102	2.0170	0.7099
13	1.0713	0.3747	1.3285	0.4566	1.6638	0.5917	2.3392	0.8233
14	1.2289	0.4298	1.5239	0.5238	1.9085	0.6787	2.6833	0.9444
15	1.3964	0.4884	1.7316	0.5952	2.1686	0.7712	3.0490	1.0731
16	1.5737	0.5504	1.9514	0.6707	2.4439	0.8691	3.4361	1.2093
17	1.7606	0.6158	2.1832	0.7504	2.7343	0.9724	3.8443	1.3530
18	1.9572	0.6845	2.4270	0.8342	3.0396	1.0810	4.2736	1.5041
19	2.1633	0.7566	2.6826	0.9221	3.3597	1.1948	4.7236	1.6625
20	2.3789	0.8320	2.9499	1.0140	3.6945	1.3139	5.1943	1.8282
21	2.6038	0.9107	3.2288	1.1098	4.0438	1.4381	5.6855	2.0010
22	2.8381	0.9926	3.5193	1.2097	4.4076	1.5675	6.1970	2.1810
23	3.0816	1.0777	3.8213	1.3135	4.7858	1.7020	6.7287	2.3682
24	3.3343	1.1661	4.1346	1.4212	5.1783	1.8416	(1)	2.5624
25	3.5961	1.2577	4.4593	1.5328	5.5849	1.9862	(1)	2.7636

(1) Exceeds 5.0 feet per second velocity

(2) Flow area, square feet

Table 5.11
IPS-ID POLYBUTYLENE WATER SERVICE PIPE
FRICTION LOSS ft/100 ft
ASTM D2662, SDR 11.5, 160 psi 0 73.4° F
Hazen Williams C = 150

Q Gallons per min.	3/4 inch 0.00370 A 0.824 ID	1 inch 0.00600 A 1.049 ID	1-1/4 inch 0.01039 A 1.380 ID	1-1/2 inch 0.01414 A 1.610 ID	2 inch 0.02330 A 2.067 ID
1	0.2494	0.0770	0.0202	0.0096	0.0028
2	0.9003	0.2778	0.0731	0.0345	0.0102
3	1.9077	0.5886	0.1548	0.0731	0.0216
4	3.2499	1.0028	0.2637	0.1245	0.0369
5	4.9128	1.5159	0.3987	0.1882	0.0557
6	6.8859	2.1248	0.5588	0.2637	0.0781
7	9.1609	2.8267	0.7434	0.3509	0.1039
8	11.7308	3.6198	0.9519	0.4493	0.1331
9	(1)	4.5020	1.1839	0.5588	0.1655
10	(1)	5.4720	1.4390	0.6792	0.2011
11	(1)	6.5282	1.7168	0.8103	0.2400
12	(1)	7.6696	2.0170	0.9520	0.2819
13	(1)	8.8950	2.3392	1.1041	0.3270
14	(1)	(1)	2.6833	1.2665	0.3751
15	(1)	(1)	3.0490	1.4391	0.4262
16	(1)	(1)	3.4361	1.6218	0.4803
17	(1)	(1)	3.8443	1.8145	0.5374
18	(1)	(1)	4.2736	2.0171	0.5973
19	(1)	(1)	4.7236	2.2296	0.6603
20	(1)	(1)	5.1943	2.4517	0.7260
21	(1)	(1)	5.6855	2.6836	0.7947
22	(1)	(1)	6.1970	2.9250	0.8662
23	(1)	(1)	6.7287	3.1760	0.9405
24	(1)	(1)	(1)	3.4364	1.0176
25	(1)	(1)	(1)	3.7062	1.0976

(1) Exceeds 5.0 feet per second velocity

(2) A = Flow area, square feet

Table 5.12
CPS (Copper Pipe Size) POLYBUTYLENE WATER SERVICE PIPE
FRICTION LOSS ft/100 ft
ASTM D2666, SDR 13.5, 160 psi @ 73.40° F
Hazen Williams C = 150

Q Gallons per min.	3/4 inch 0.00303 A 0.745 ID	1 inch 0.00499 A 0.957 ID	1-1/4 inch 0.00748 A 1.171 ID	1-1/2 inch 0.01050 A 1.385 ID	2 inch 0.01789 A 1.811 ID
1	0.4075	0.1203	0.0450	0.0199	0.0054
2	1.4709	0.4344	0.1626	0.0718	0.0194
3	3.1166	0.9204	0.3445	0.1521	0.0412
4	5.3094	1.5681	0.5868	0.2591	0.0702
5	8.0262	2.3704	0.8871	0.3917	0.1061
6	11.2497	3.3225	1.2434	0.5490	0.1487
7	(1)	4.4202	1.6541	0.7304	0.1978
8	(1)	5.6602	2.1182	0.9353	0.2533
9	(1)	7.0397	2.6345	1.1633	0.3151
10	(1)	8.5564	3.2021	1.4139	0.3830
11	(1)	10.2081	3.8202	1.6868	0.4569
12	(1)	(1)	4.4881	1.9817	0.5368
13	(1)	(1)	5.2052	2.2984	0.6226
14	(1)	(1)	5.9709	2.6365	0.7141
15	(1)	(1)	6.7846	2.9958	0.8115
16	(1)	(1)	7.6459	3.3761	0.9145
17	(1)	(1)	(1)	3.7772	1.0231
18	(1)	(1)	(1)	4.1989	1.1374
19	(1)	(1)	(1)	4.6411	1.2571
20	(1)	(1)	(1)	5.1036	1.3824
21	(1)	(1)	(1)	5.5862	1.5131
22	(1)	(1)	(1)	6.0888	1.6492
23	(1)	(1)	(1)	6.6112	1.7907
24	(1)	(1)	(1)	(1)	1.9376
25	(1)	(1)	(1)	(1)	2.0897

(1) Exceeds 5.0 feet per second velocity

(2) A = Flow area, square feet

Table 5.13
CPS (Copper Pipe Size) POLYBUTYLENE WATER SERVICE PIPE
FRICITION LOSS ft/100 ft
ASTM D2666, SDR 9, 250 psi 0 73.40 F
Hazen Williams C = 150

Q Gallons per min.	3/4 inch 0.00248 A 0.675 ID	1 inch 0.00408 A 0.865 ID	1-1/4 inch 0.00617 A 1.064 ID	1-1/2 inch 0.00865 A 1.259 ID	2 inch 0.01480 A 1.649 ID
1	0.6589	0.1969	0.0718	0.0316	0.0085
2	2.3784	0.7107	0.2593	0.1142	0.0307
3	5.0395	1.5059	0.5493	0.2420	0.0650
4	8.5853	2.5654	0.9358	0.4123	0.1108
5	12.9783	3.8781	1.4146	0.6233	0.1675
6	(1)	5.4356	1.9828	0.8736	0.2347
7	(1)	7.2315	2.6379	1.1623	0.3123
8	(1)	9.2602	3.3779	1.4883	0.3999
9	(1)	11.5172	4.2012	1.8511	0.4973
10	(1)	(1)	5.1064	2.2499	0.6045
11	(1)	(1)	6.0921	2.6842	0.7212
12	(1)	(1)	7.1572	3.1535	0.8473
13	(1)	(1)	8.3007	3.6574	0.9826
14	(1)	(1)	(1)	4.1954	1.1272
15	(1)	(1)	(1)	4.7672	1.2808
16	(1)	(1)	(1)	5.3723	1.4434
17	(1)	(1)	(1)	6.0106	1.6149
18	(1)	(1)	(1)	6.6818	1.7952
19	(1)	(1)	(1)	7.3854	1.9842
20	(1)	(1)	(1)	(1)	2.1819
21	(1)	(1)	(1)	(1)	2.3883
22	(1)	(1)	(1)	(1)	2.6031
23	(1)	(1)	(1)	(1)	2.8265
24	(1)	(1)	(1)	(1)	3.0583
25	(1)	(1)	(1)	(1)	3.2984

(1) Exceeds 5.0 feet per second velocity

(2) A = Flow area, square feet

Table 5.14
BLACK OR GALVANIZED STEEL PIPE
FRICTION LOSS ft/100 ft
Schedule 40 (Standard)
Seamless & Electric Welded ASTM A120
Hazen Williams C = 100

Q Gallons per min.	1/2 inch 350 psi 0.0021 A 0.622 ID	3/4 inch 350 psi 0.0037 A 0.824 ID	1 inch 350 psi 0.0060 A 1.049 ID	1-1/4 inch 500 psi 0.0104 A 1.380 ID	1-1/2 inch 500 psi 0.0141 A 1.610 ID	2 inch 500 psi 0.0233 A 2.067 ID	2-1/2 inch 500 psi 0.0332 A 2.469 ID	3 inch 500 psi 0.0513 A 3.068 ID
1	2.0792	0.5285	0.1631	0.0429	0.0202	0.0060	0.0025	0.0009
2	7.5050	1.9077	0.5886	0.1548	0.0731	0.0216	0.0091	0.0032
3	15.9018	4.0420	1.2472	0.3280	0.1548	0.0458	0.0193	0.0067
4	27.0903	6.8859	2.1248	0.5588	0.2637	0.0781	0.0329	0.0114
5	40.9521	10.4094	3.2120	0.8447	0.3987	0.1181	0.0497	0.0173
6	57.3995	14.5900	4.5020	1.1839	0.5588	0.1655	0.0696	0.0242
7	76.3630	19.4103	5.9894	1.5751	0.7434	0.2202	0.0926	0.0322
8	97.7858	24.8556	7.6696	2.0170	0.9520	0.2819	0.1186	0.0412
9	121.6193	30.9137	9.5390	2.5085	1.1840	0.3506	0.1476	0.0512
10	(1)	37.5740	11.5941	3.0490	1.4391	0.4262	0.1793	0.0623
11	(1)	44.8270	13.8322	3.6376	1.7169	0.5085	0.2140	0.0743
12	(1)	52.6646	16.2506	4.2736	2.0171	0.5973	0.2514	0.0873
13	(1)	61.0791	18.8470	4.9564	2.3394	0.6928	0.2915	0.1012
14	(1)	70.0639	21.6194	5.6855	2.6836	0.7947	0.3344	0.1161
15	(1)	79.6125	24.5658	6.4603	3.0493	0.9030	0.3800	0.1319
16	(1)	89.7194	27.6845	7.2804	3.4364	1.0176	0.4283	0.1487
17	(1)	(1)	30.9738	8.1455	3.8447	1.1386	0.4791	0.1663
18	(1)	(1)	34.4321	9.0549	4.2739	1.2657	0.5326	0.1849
19	(1)	(1)	38.0581	10.0085	4.7240	1.3990	0.5887	0.2044
20	(1)	(1)	41.8504	11.0058	5.1948	1.5384	0.6474	0.2248
21	(1)	(1)	45.8077	12.0465	5.6860	1.6838	0.7086	0.2460
22	(1)	(1)	49.9289	13.1303	6.1975	1.8353	0.7723	0.2681
23	(1)	(1)	54.2129	14.2569	6.7293	1.9928	0.8386	0.2912
24	(1)	(1)	58.6585	15.4260	7.2811	2.1562	0.9074	0.3150
25	(1)	(1)	63.2648	16.6373	7.8529	2.3255	0.9786	0.3398

(1) Exceeds 10.0 feet per second velocity

(2) A = Flow area, square feet

(3) It is good design practice to design steel pipe operating pressure for not more than 50% of test pressure. The pressures shown are 50% of ASTM A120 test pressures.

Table 5.15
BLACK OR GALVANIZED STEEL PIPE
FRICITION LOSS ft/100 ft
Schedule 80 (Standard)
Seamless & Electric Welded ASTM A120
Hazen Williams C = 100

Q Gallons per min.	1/2 inch 424 psi 0.0016 A 0.546 ID	3/4 inch 425 psi 0.0030 A 0.742 ID	1 inch 425 psi 0.0050 A 0.957 ID	1-1/4 inch 750 psi 0.0089 A 1.278 ID	1-112 inch 750 psi 0.0123 A 1.500 ID	2 inch 750 psi 0.0205 A 1.939 ID	2-1/2 inch 750 psi 0.0294 A 2.323 ID	3 inch 750 psi 0.0459 A 2.900 ID
1	3.9223	0.8805	0.2550	0.0623	0.0286	0.0082	0.0034	0.0012
2	14.1580	3.1784	0.9204	0.2250	0.1031	0.0295	0.0123	0.0042
3	29.9983	6.7346	1.9503	0.4767	0.2185	0.0626	0.0260	0.0088
4	51.1052	11.4730	3.3225	0.8122	0.3723	0.1066	0.0442	0.0150
5	77.2552	17.3436	5.0226	1.2278	0.5628	0.1612	0.0669	0.0227
6	108.2829	24.3093	7.0397	1.7209	0.7888	0.2259	0.0937	0.0318
7	144.0573	32.3405	9.3655	2.2894	1.0494	0.3006	0.1247	0.0423
8	(1)	41.4133	11.9929	2.9317	1.3438	0.3849	0.1596	0.0542
9	(1)	51.5070	14.9160	3.6462	1.6713	0.4787	0.1986	0.0674
10	(1)	62.6040	18.1296	4.4318	2.0314	0.5818	0.2413	0.0819
11	(1)	74.6888	21.6292	5.2872	2.4235	0.6942	0.2879	0.0977
12	(1)	87.7474	25.4108	6.2117	2.8472	0.8155	0.3383	0.1148
13	(1)	101.7673	29.4709	7.2041	3.3022	0.9458	0.3923	0.1332
14	(1)	(1)	33.8060	8.2639	3.7879	1.0850	0.4500	0.1527
15	(1)	(1)	38.4133	9.3901	4.3041	1.2328	0.5114	0.1736
16	(1)	(1)	43.2899	10.5822	4.8506	1.3893	0.5763	0.1956
17	(1)	(1)	48.4333	11.8395	5.4269	1.5544	0.6447	0.2188
18	(1)	(1)	53.8411	13.1614	6.0328	1.7280	0.7167	0.2433
19	(1)	(1)	59.5110	14.5474	6.6681	1.9099	0.7922	0.2689
20	(1)	(1)	65.4410	15.9970	7.3325	2.1003	0.8711	0.2957
21	(1)	(1)	71.6290	17.5097	8.0259	2.2989	0.9535	0.3236
22	(1)	(1)	78.0733	19.0850	8.7480	2.5057	1.0393	0.3528
23	(1)	(1)	(1)	20.7225	9.4986	2.7207	1.1285	0.3830
24	(1)	(1)	(1)	22.4218	10.2775	2.9438	1.2210	0.4144
25	(1)	(1)	(1)	24.1825	11.0845	3.1749	1.3169	0.4470

- (1) Exceeds 10.0 feet per second velocity
- (2) A = Flow area, square feet
- (3) It is good design practice to design steel pipe operating pressure for not more than 50% of test pressure. The pressures shown are 50% of ASTM A120 test pressures.

5.10 PVC PIPE FITTINGS

Schedule 40 and 80 solvent weld and threaded fittings are covered by the following ASTM standards:

D2624 - Threaded Polyvinyl Chloride (PVC) Plastic Pipe Fittings, Schedule 80

D2466 - Polyvinyl Chloride (PVC) Plastic Pipe Fittings, Schedule 40

D2467 - Socket-Type Polyvinyl Chloride (PVC) Plastic Pipe Fittings, Schedule 80

These standards deal mainly with workmanship, materials, dimensions, tolerances, and testing. There are no pressure rating standards for PVC fittings in the ASTM specifications. The only pressure standards specified are for burst pressure.

One analysis, based very limited real data, proposes the upper limit working pressures for Schedule 40 and 80 PVC fittings as tabulated in Table 5.16. Use this as a general guide only. Actual allowable working pressures may vary widely with field conditions, particularly the frequency and degree of surge pressures anticipated. On high pressure pipelines, metal or other alternative type fittings may be needed.

Table 5.16
**Estimated Upper Limit Working Pressures for
 Schedule 40 and Schedule 80 PVC Fittings**

Nominal Diameter (in)	Outside Diameter (in)	Schedule 40 Pressure Rating		Schedule 80 Pressure Rating	
		Burst (psi)	Working (psi)	Burst (psi)	Working (psi)
1/2	0.840	1910	358	2720	509
3/4	1.050	1540	289	2200	413
1	1.315	1440	270	2020	378
1-1/4	1.660	1180	221	1660	312
1-1/2	1.900	1060	198	1510	282
2	2.375	890	166	1290	243
2-1/2	2.875	970	182	1360	255
3	3.500	840	158	1200	225